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A review study of the current research on energy hub for energy positive neighborhoods

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Abstract

Energy positive neighborhoods and cities are emerging concepts aimed at addressing the current energy and environmental sustainability challenges. In this paper, the concept and current research on energy hubs relating to energy positive neighborhoods are presented. In addition to discussing advantages and challenges of energy positive neighborhoods and energy hubs, opportunities for future research and development are also conversed.

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1. Introduction

With the depletion of fossil fuels and the issue of global warming, people try to integrate different forms of energy sources into the energy grids. The aim of doing so is to confront these problems and to move towards a sustainable future. These modifications change the currently centralized energy grids into distributed infrastructures. As a result of the use of different forms of energy sources, the future energy network will comprise of more intense integration of different energy carriers than electricity, gas and oil. In order to accommodate these changes, new

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research concepts try to integrate and hybridize different energy carriers (natural gas, oil, hot water, hydrogen, electricity etc.) to devise smart energy systems with the ability of interoperability.

Buildings are a major aspect that should be focused on, in terms of energy usage in the distributed energy grids. Buildings will play a vital role in the future smart energy grids with changing energy policies and targets. The “*International Energy Agency*” states that demand side activities should be a priority in energy policies and decisions regarding sustainable energy systems [1]. Apart from the collective sustainable energy targets, each country has their own building related energy goals. For example, according to the “*Energy Performance Building Directive*” all new buildings will be required to be nearly zero energy by 2021 for member states of the EU [2,3].

However, the energy dynamics of buildings cannot be fully analyzed when they are considered as isolated single units. They are always connected with several outside systems. Therefore, it is beneficial to consider the buildings with their connected systems as a collective unit at the neighborhood level [4] and achieve energy neutrality/positivity at the neighborhood level. With the distribution/decentralization of the energy grids, the neighborhood can be seen as a whole with local supply, demand and local energy management. The complexity of the local energy management systems increases with the number of energy sources, storage units integrated, and the demand requirements in the neighborhood. Therefore, optimal coordination of these separate systems is crucial.

Energy hub and smart building clusters are two research concepts that can be found in the literature for optimal coordination and energy management at the neighborhood level. Authors of [5] indicate that in the literature, the first attempt of a bi-level operation decision framework using the building cluster concept can be found in the year 2012 [6] while the energy hub was introduced in the year 2007 [7]. Yet, concepts which give attention to the energy management at the neighborhood level with a futuristic view on multi-carrier energy grids and achieving energy positivity at the neighborhood level are still lacking. Therefore, the aim of this paper is to review research papers on energy hubs and identify the potential of this concept to realize energy positive neighborhoods. The first section of the paper gives an introduction to energy hubs. This is followed by the review study. Finally, an approach to achieve energy positivity at the neighborhood level with this concept and the challenges hindering the practical realization of energy hub are discussed.

Nomenclature

BEMS	Building Energy Management System	IT	Italy
SW	Switzerland	CN	Canada
IR	Iran	NW	Norway
CH	China	US	United States of America
EPN	Energy Positive Neighborhood	GAMS	General Algebraic Modeling System
ICT	Information and Communication Technology	EU	European Union

1.1. Energy Hub

The concept of Energy Hub can be defined as a central point where multiple energy carriers meet each other and respective energy flows can be converted, conditioned, stored and finally distributed according to the demand requirements in an optimal manner [7,8]. The modeling concept of an energy hub describes the relation between input and output energy flows and can be used to optimize the energy consumption during planning and operation. Authors of [9] equate this to a flexible interface between different energy infrastructures.

It is a possibility that the energy carriers exist today will be diversified into different forms in the future. The energy hub concept could still be used even if the forms of energy carriers change over time. Fig. 1 illustrates an energy hub composite of different energy carriers. After an optimal coordination between supply and demand, it provides different demand requirements at the output.

This concept can be designed in different spatial scales according to the resources available and the level of complexity needed. In [10–12] authors have conducted their research for a residential energy hub model aimed at a smart home with residential combined heat and power (CHP) unit as a cogeneration technology and using plug-in hybrid electric vehicles. In [13] the authors discuss the importance of integrating and managing energy from

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